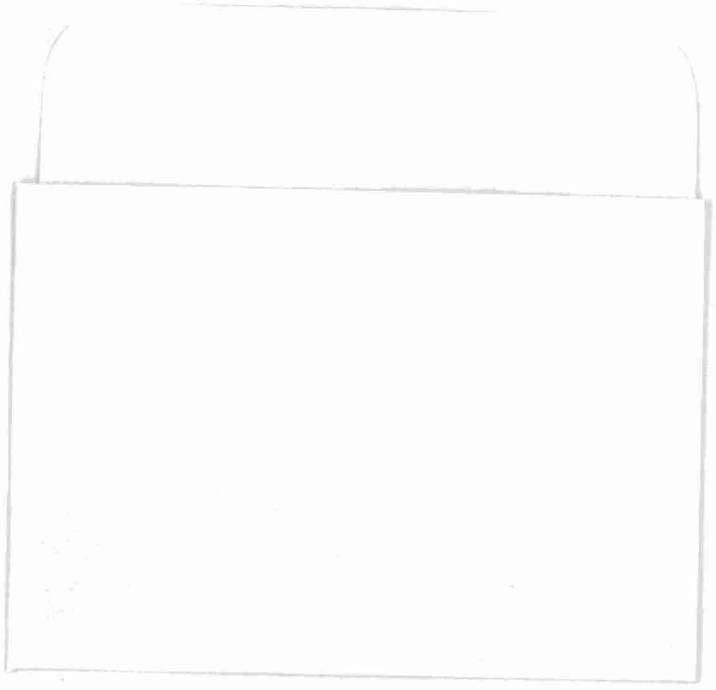
INTRODUCTION TO

POPULAR TREATMENT METHODS

FOR MUNICIPAL WASTES AND WATER SUPPLIES

Process Descriptions and Flow Diagrams

ONTARIO WATER RESOURCES COMMISSION
801 Bay Street, Toronto 5, Ontario



INTRODUCTION

This booklet has been prepared as a general introduction to some of the popular treatment methods utilized in water pollution control plants to reclaim community wastewater, and in water treatment plants which purify community drinking water.

The material is designed to provide a source of technical and other information for educational purposes for interested persons.

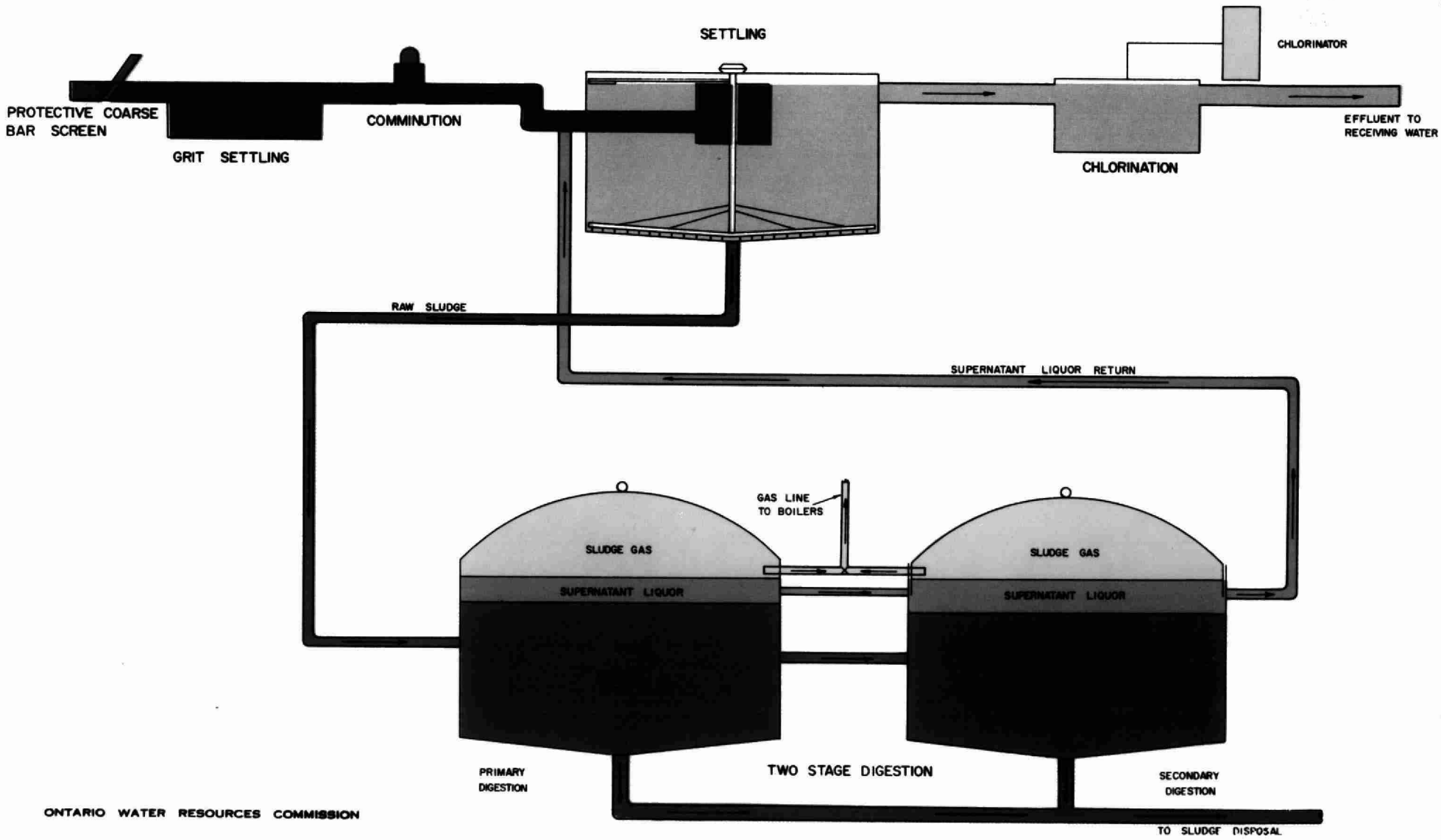
No CLEAN WATER program could succeed without the successful operation of such projects by or on behalf of municipalities.

WHY WATER POLLUTION CONTROL PLANTS?

Discharge of untreated sanitary and industrial wastes to any watercourse, particularly in the immediate discharge area, renders that watercourse unusable for practically all purposes. It makes the water offensive to humans through its odor and appearance and a menace to health. It upsets the cycle of plant and animal life through dissipation of the water's oxygen content, thus rendering it uninhabitable for fish. This is polluted water.

To prevent this condition there are sewage treatment plants, or, if you wish, water pollution control plants, for the treatment of sanitary, or domestic wastes, and means for treating most industrial wastes. Pollution of watercourses primarily can be prevented by eliminating all waste discharges. However, efficient treatment of wastes will produce a satisfactory effluent for discharge to waterways. The first section of this booklet contains brief descriptions of the more popular methods of treating domestic wastes.

PRIMARY SEWAGE TREATMENT



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PRIMARY TREATMENT

Primary treatment is mechanical in nature, where settling tanks are used to remove the settleable solids, floating scum and grease from the waste water. This form of treatment is used only when it will meet the water quality requirements of the receiving body.

Settling tanks (clarifiers), equipped with sludge and scum removal mechanisms, provide a detention period of approximately two hours for the incoming wastewater. This detention period allows the waste particles to settle to the bottom of the tanks, from where it is removed by pumps for conditioning prior to disposal. The sludge removed is pumped to a digester or other treatment facility where it is processed or dewatered before final disposal.

Primary treatment usually precedes biological treatment which is carried out in secondary plants.

To summarize: Primary treatment removes the heavier particles, scum and grease from the wastewater. The effluent produced is of a lower standard of quality than is achieved in complete treatment. The amount of solids removed ranges from 40 to 60 per cent.

ACTIVATED SLUDGE TREATMENT

The activated sludge process is a method of complete biological treatment which produces a high quality effluent.

This is a secondary process, usually carried out following primary treatment. It removes the finely divided, suspended and dissolved materials remaining in the wastewater.

Biological communities of micro-organisms are developed and maintained in aeration tanks where they are supplied with a plentiful supply of oxygen. The air supply can be provided by compressed air, which is piped directly into the tanks, or by means of mechanical agitators, which revolve and disperse the liquid surface to effect transfer of atmospheric oxygen into the tank's contents. Besides providing dissolved oxygen for the micro-organisms, the air, or agitation, also produces a roll in the tank and prevents settling of solids.

As the organic impurities are assimilated by the micro-organisms, the resulting sludge formation is light and flocculent and can readily be settled. This sludge is the vehicle upon which the bacteria grow and provides the means for maintaining the process. This sludge floc is referred to as activated sludge because of the biological communities growing in and upon it.

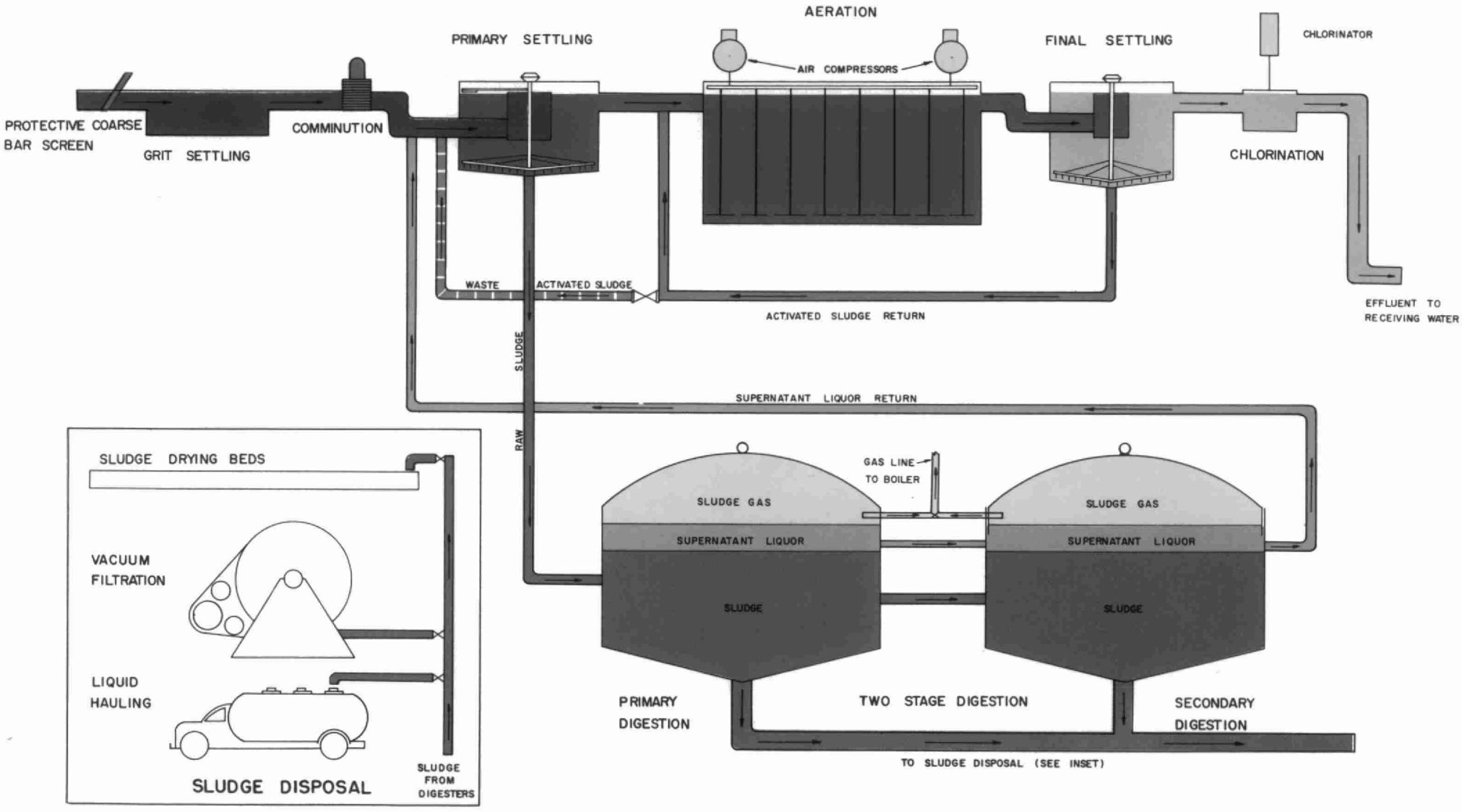
Final settling tanks provide the means for removing and reclaiming this sludge floc. As the effluent from the aeration tanks passes through these settling tanks, the settling sludge floc is removed and returned to the process by means of pumps or air lifts and is discharged into the aeration tanks again, along with the effluent flowing from the primary settling tanks.

To summarize: Air is supplied to the micro-organisms, which in turn oxidize the finely divided, suspended and dissolved organic materials in the wastewater. This provides a high degree of purification and a clear effluent. The amount of solids removed ranges from 90 to 95 per cent.

SEWAGE TREATMENT

BY THE

ACTIVATED SLUDGE PROCESS



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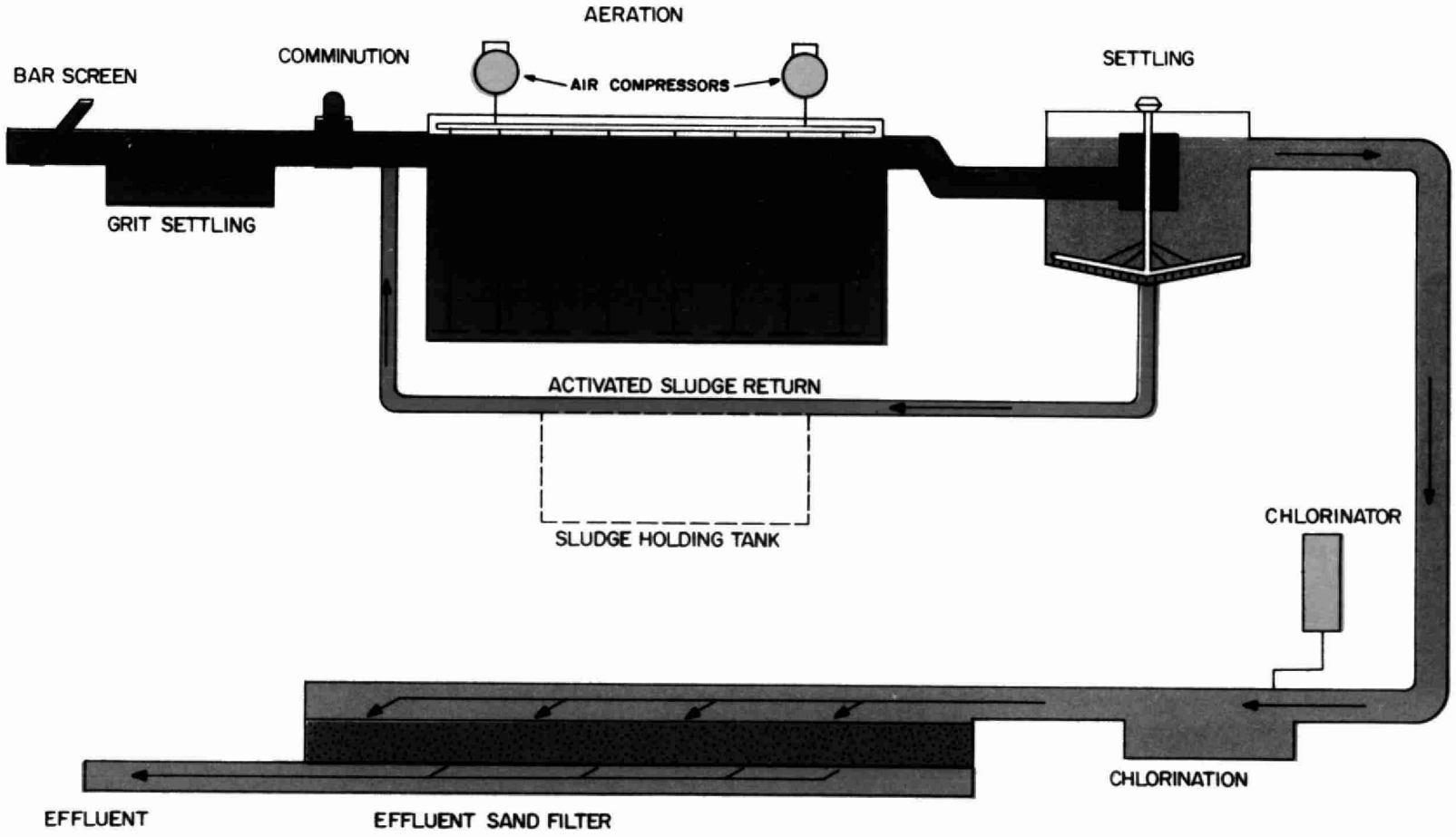
SEWAGE TREATMENT

BY THE

EXTENDED AERATION PROCESS



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EXTENDED AERATION TREATMENT

The extended aeration process is another method of biological treatment that produces a high quality effluent.

This process is identical to the activated sludge process in its biological application, but has no primary settling and the solids contained in the wastewater are oxidized through an extended aeration period.

Biological communities of micro-organisms are developed and maintained in aeration tanks where they are supplied with a plentiful supply of oxygen. The air supply can be provided by compressed air, which is piped directly into the tank, or by means of mechanical agitators, which revolve and disperse the liquid surface to effect transfer of atmospheric oxygen into the tank's contents. Besides providing dissolved oxygen for the micro-organisms, the air, or agitation, also produces a roll in the tank and prevents settling of solids.

As the organic impurities are assimilated by the micro-organisms, the resulting flocculent sludge can readily be settled. This sludge is the vehicle upon which the bacteria grow and provides the means for maintaining the process. This sludge is referred to as activated sludge because of the biological communities growing in and upon it.

Final settling tanks remove and reclaim this sludge floc. As the effluent from the aeration tanks passes through these settling tanks, the settled sludge is removed and returned to the aeration section by means of pumps or air lifts to be mixed with the incoming sewage.

The small amount of inert and oxidized matter remaining after a period of time is periodically removed to a holding tank or sludge drying bed for final disposal.

To summarize: Air is supplied to the micro-organisms, which in turn oxidize the organic materials in the wastewater. The amount of solids removed ranges from 90 to 95 per cent.

TRICKLING FILTER TREATMENT

Standard Rate Trickling Filter

The trickling filter process is carried out following primary treatment, which eliminates the heavier settleable solids, to remove the finely divided, suspended and dissolved materials remaining in the wastewater. The filter is constructed of a bed of crushed rock or other supporting media which provides a large surface area for the development and growth of colonies of micro-organisms.

Aerobic bacteria build up on the crushed rock and, as the wastewater is fed through, the organisms oxidize the organic materials contained in the water. The oxygen required by the organisms is supplied from the atmosphere.

The wastewater is discharged on the media by a rotary distributor which places an even flow over the entire surface area.

The underdrain system, constructed from special tile, supports the filter media and carries off the effluent. Periodically, oxidized material falls away from the filter media. A final settling tank provides sedimentation to the filter effluent and collects these oxidized particles.

High Rate Trickling Filter

Recirculation provides improved biological treatment and is especially useful in treating certain types of industrial wastes. The methods and points of recirculation vary with design and equipment, but the filter is constructed the same as the Standard Rate Filter.

To summarize: The aerobic micro-organisms, supplied with oxygen, oxidize the organic matter and produce a rapid settling. This form of treatment produces an intermediate degree of purification. The amount of solids removed ranges from 75 to 85 per cent.

TREATMENT BY A WASTE STABILIZATION POND

A waste stabilization pond makes use of natural purification processes through the regulating of such processes. For instance, in nature, micro-organisms, through time, react with organic material and break it down into carbon dioxide and micobial cell material which is nuisance free. Natural purification is achieved by microbes present in soil, by oxygen, by organic material (food for microbes) and dissolved materials working together.

In a stabilization pond, loading, depth, soil conditions and liquid losses, all of which are controlled, together with wind action, sunlight, algae growth and oxygen are contributing factors in providing the environment necessary for the development of the aerobic bacterial action and photosynthetic oxidation required to stabilize the wastes.

The micro-organisms cultivated convert much of the organic carbon in the wastes to carbon dioxide. This carbon dioxide, together with dissolved minerals and sunlight, provide conditions for the growth of algae, which in turn provides a plentiful supply of oxygen for the micro-organisms. When the organic materials have been converted into bacterial bodies, dissolved minerals and gasses, the stable liquid portion remaining is discharged to a receiving body or evaporates into the atmosphere.

To summarize, the wastewater is collected in a lagoon where, by regulating the natural purification process, the organic materials are converted and the wastewater purified. This is accomplished in such a manner that no nuisance conditions develop.

In order to allow a better understanding of this, the following description of the physiology of micro-organisms is outlined.

Bacteria

Bacteria are microscopic organisms of various shapes and they constitute the most elemental forms of life, and multiply with great rapidity. Their nourishment consists of albuminous substances, which they convert into complex chemical compounds. The study of the chemistry of bacteria has shown that many of them do not grow upon living matter, but will flourish upon decomposing and putrefying substances, such as the organic waste materials found in sanitary wastes. Bacteria also convert inert matter into available plant food, changing organic nitrogenous substances into soluble nitrates.

Physiology of the Bacteria — Nutrition

Most of the food utilized by bacteria is in the form of insoluble solids or colloidal solutions. Bacteria possess no mechanisms for ingesting such material. Most animals are capable of taking into their digestive tracts solids and particulate foods, tranforming them into a soluble condition through the process of digestion. In the case of bacteria, the digestive processes concerned in transforming insoluble foods into a soluble condition must take place outside the organisms' bodies.

The chemical changes involved are the same whether they take place within or outside the body of the organism. The active agencies in digestive juices are "enzymes", that is, organic protein catalysts synthesized only by living cells.

Enzymes are separated into two categories, extracellular (exoenzymes) and intracellular (endoenzymes). The extracellular enzymes are primarily of value in the activation of reactions involved in changing insoluble foods into soluble, or reducing the size of the molecules of food so that they can readily diffuse into the cell. Intracellular enzymes continue the process of liberating energy, or reducing the food further so that it can be used in the synthesis of the organisms' bodies, or recombine the dissimilated food for the construction of protoplasm.

Respiration

There are two classifications of bacteria relating to their respiration, aerobic and anaerobic. Aerobic is designated to the majority of bacteria which utilize molecular oxygen in the transformation of organic compounds into the inorganic state. Anaerobic is designated to bacteria which utilize compounds in their environment to obtain their oxygen requirements. The bio-chemical changes involved in microbic respiration are very complex. Nevertheless, most, if not all, of the energy-liberating changes are basically oxidative in nature and all such processes are frequently spoken of collectively as "biological oxidation".

Algae

The simplest plants are called thallophytes, a great group possessing no true roots, leaves or stems. Their plant bodies or "thallus" lack the structural differentiation of the higher forms, such as mosses, ferns, and seed-bearing plants. The thallophytes are divided into two sub-groups, the algae and the fungi, depending on whether or not they contain the green pigment chlorophyll. The algae are chlorophyll-bearing, whereas the fungi are devoid of this material and are generally referred to as the colorless plants.

The algae are chiefly aquatic and are found in every water supply exposed to sunlight. Those which live

on land grow only where there is abundant moisture or in combination with fungi to form lichens which commonly grow on rocks. In size and structure, they range from single-celled organisms through a variety of microscopic colonial forms to large multicellular plants, such as the giant seaweeds. Some algae are flagellated one-celled individuals which may be classified with either the protozoa or the algae.

Physiology of the Algae — Nutrition

As other green plants, algae synthesize their cell substance from simple substances in nature, i.e., they grow on mineral salts, carbon dioxide and water.

The basic process in the conversion of simple compounds into complex cell substance is "photosynthesis". In photosynthesis the energy of sunlight is captured by the chlorophyll and utilized to combine the carbon, hydrogen and oxygen of carbon dioxide and water into key organic substances from which the plant protoplasm and reserve foods are made. Oxygen is given off in the photosynthetic process. Carbon dioxide and water are then the raw materials which can be built up into molecules of sugar, starch and other polysaccharides or fats. Suitable dissolved nitrogen compounds taken from the water are incorporated by the plants into plant protein. The chief food reserves of algae are stored in the cells as insoluble polysaccharides, generally starch, or as fats.

Respiration

Respiration in algae is fundamentally the same as in other living organisms. Intracellular compounds are broken down by a series of oxidative reactions with accompanying release of energy to the cell. However, in algae the rate of their photosynthesis is normally faster than their respiration. These organisms, therefore, release more oxygen than they use and absorb more carbon dioxide than they release, while animals and other nonphotosynthetic organisms release carbon dioxide and absorb oxygen from their environment.

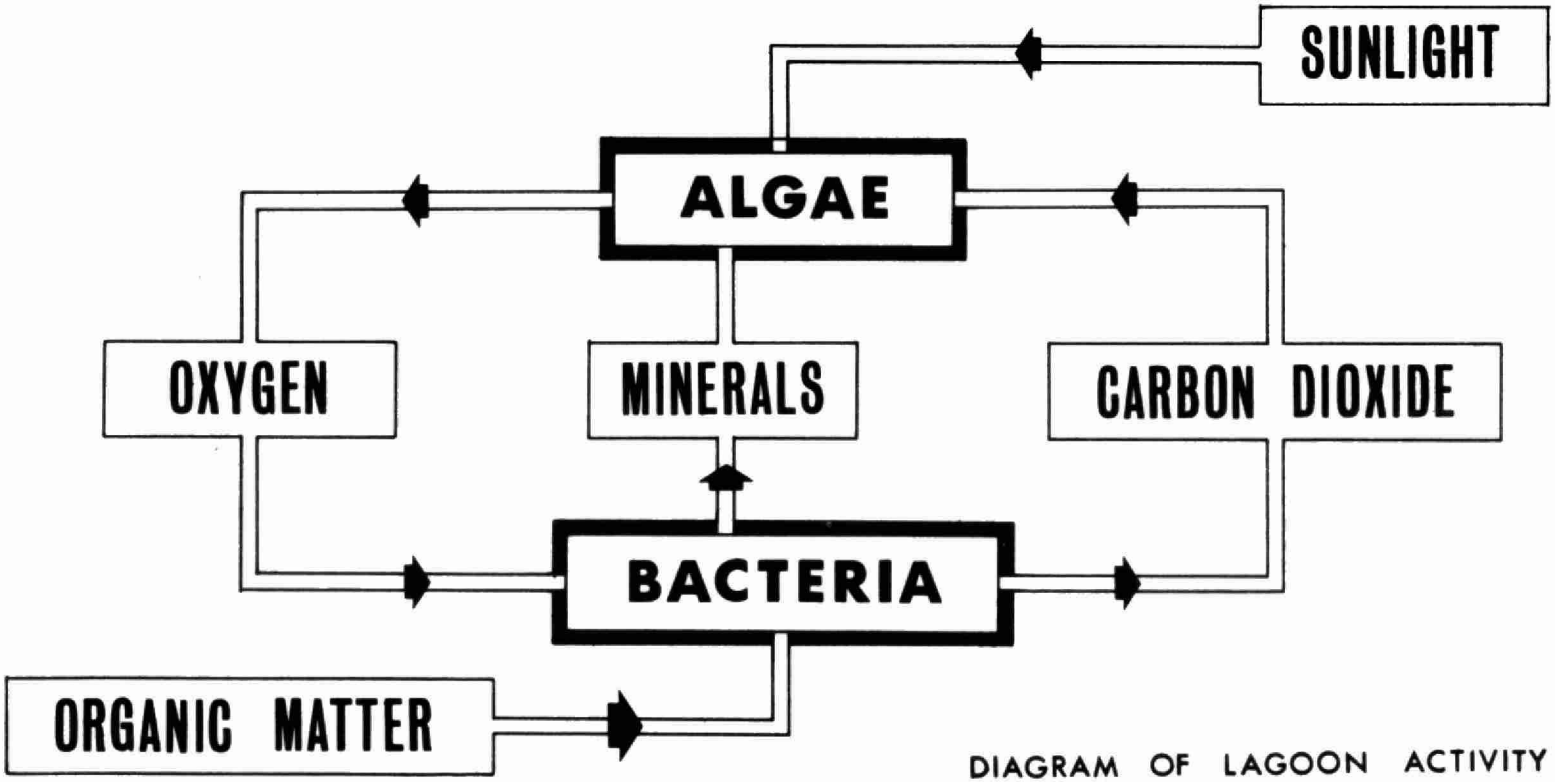


DIAGRAM OF LAGOON ACTIVITY

AERATED LAGOON

An aerated lagoon makes use of natural purification processes similar to a waste stabilization pond, with the exception that the retention period is greatly reduced and algae play no part in the oxidation process.

The lagoon is equipped with an aerating device which allows the contents to absorb a greater amount of atmospheric oxygen by blowing air into the contents to provide a greater amount of oxygen to the environment. This eliminates the necessity for prolonged retention of the wastewater by increasing the efficiency of the oxidation activity.

This form of treatment is used for smaller communities and some types of industrial wastes.

OXIDATION DITCH

An oxidation ditch is a specially constructed retention channel equipped with a rotary aerating device, which is followed by a settling tank.

As wastewater is discharged into the ditch the aerating rotor maintains circulation of the contents of the ditch and allows for a greater absorption of atmospheric oxygen by the micro-organisms for the oxidation activity.

After retention, the wastewater passes into a settling tank where the oxidized matter (sludge) is settled out for return to the ditch or discharged for final disposal. The clarified effluent is then discharged to a receiving body.

This form of treatment is similar in operation to the extended aeration process and is used in smaller communities where conventional forms of treatment are prohibitive in cost.

TERTIARY TREATMENT

Secondary treatment plant effluents can create some undesirable conditions in some receiving streams through adverse effects on the dissolved oxygen levels which result in unwanted changes in the living organisms of the streams. Also, these discharges can bring about excess growth of algae and other aquatic plants.

To arrest these conditions, an advanced type of treatment called tertiary is being developed as a third or "polishing" stage to follow conventional secondary treatment processes, for the further reduction of organic content. This will improve receiving water conditions as far as the dissolved oxygen levels are concerned. Another important result of tertiary treatment is the reduction of nutrient levels which algae utilizes for growth.

No tertiary treatment form is typical. This third stage of cleaning up wastewater of necessity must be adapted to the particular need of the receiving water concerned.

ADDITIONAL DESIGN FEATURES

Coarse Bar Screens

A coarse bar screen is a protective screen installed at the influent or entrance to the plant or pumping station to prevent the entry of large objects which could damage machinery or equipment.

Comminution

Comminuting (shredding) equipment is used to reduce large particles in the flow to a size suitable for handling in the treatment units. These units are installed ahead of, or behind, grit and sand removal facilities.

Grit and Sand Removal

Through the use of channels or chambers, the velocity of flow of the incoming wastewater is reduced sufficiently to allow grit and sand, which is heavier than the organic matter, to settle out for removal. When channels are utilized, the normal flow of the wastewater keeps the organic material in suspension. When chambers are utilized, organic return pumps are sometimes installed to assist in this function. Aerated grit chambers provide another means of removal. As the grit and sand settle, a suction pipe draws the contents from the bottom of the chamber and deposits it into channels or a hopper, from where the water is returned to the flow and the grit and sand collects for periodic removal. The turbulence of the water in the chamber keeps the organic material in suspension.

Effluent Filter

Where required, a sand filter is installed to filter the effluent before it is discharged to a watercourse. When receiving waters are small or very low flows are encountered during the summer months, this method of "polishing" the effluent is very effective and ensures a high degree of removal for any remaining waste materials from the final effluent before discharge.

Chlorination

Chlorinating facilities are provided to disinfect the effluent before discharge from a plant. In most cases a chlorine contact chamber is utilized for this purpose. In this chamber the final effluent undergoes a detention period of from 15 to 30 minutes to ensure a good contact with the chlorine. The effluent outfall sewer, running from the plant to the receiving waters, is sometimes utilized as a means of chlorinating the effluent. The function is essentially the same as for the chamber.

SLUDGE AND ITS TREATMENT

Sludge is composed of the solids removed from the wastewater by a treatment process.

Digestion

Digestion is the decomposition, by anaerobic bacteria, of settled solids or sludge removed from the wastewater. This is carried out in a digester, which is a specially constructed structure equipped with various piping and valve arrangements and heat transfer equipment.

The raw sludge is pumped to the digesters where it is broken down by anaerobic bacterial action, at a regulated temperature of from 90 to 95 degrees Fahrenheit. When it is thoroughly digested, it is a thick, black, odorless liquid which can be used as a soil conditioner.

A product of digestion is methane gas which is utilized as fuel for plant heat exchangers and boilers.

In smaller plants the entire process usually is carried out in one digester, but in larger plants two digesters generally are required to handle the larger volume of sludge and the process is carried out in two stages. In two stage operation the primary digester(s) initially receive the raw sludge to begin the process with the contents being agitated. The secondary digester(s) complete the process in a quiescent state.

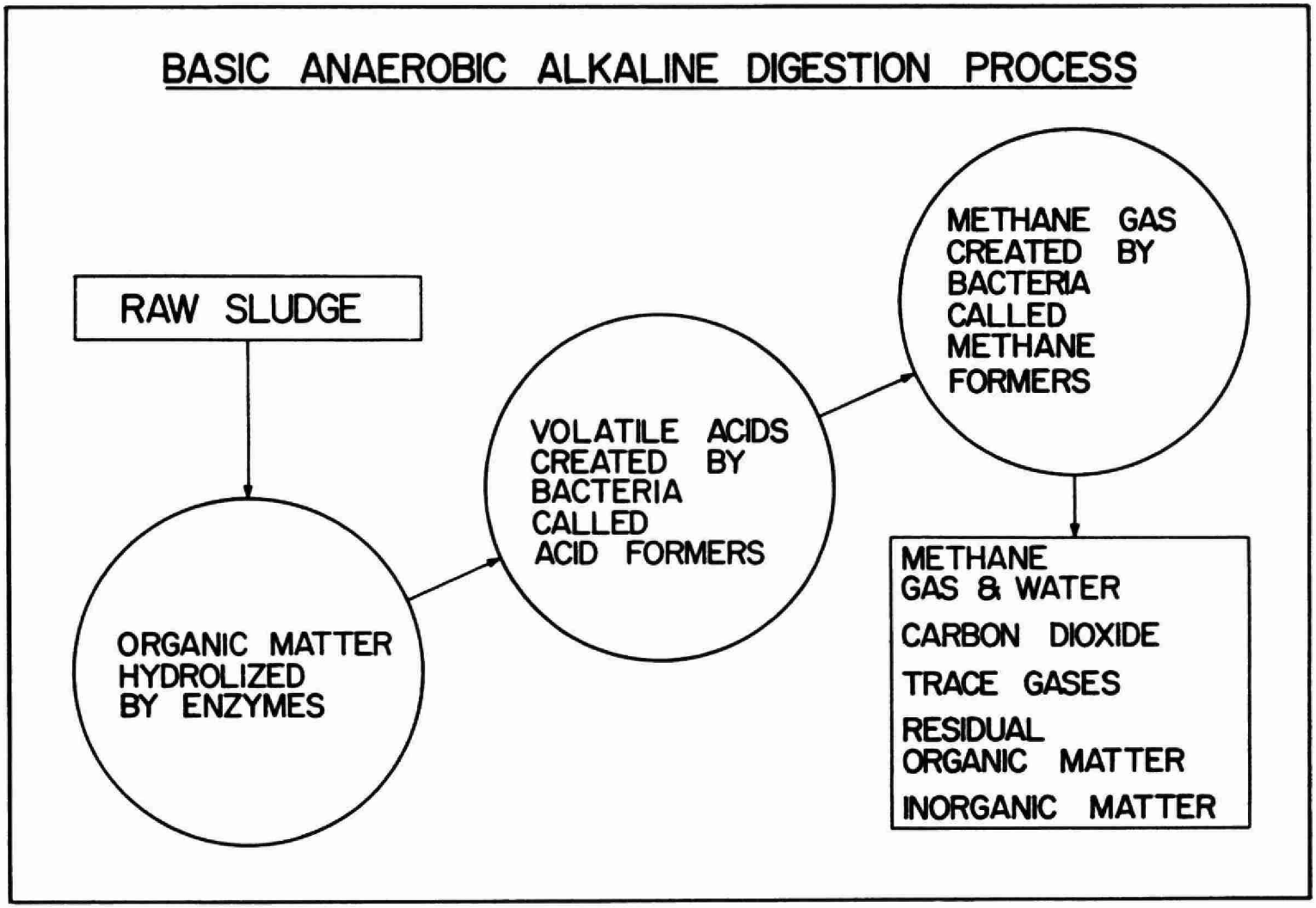
Vacuum Filtration

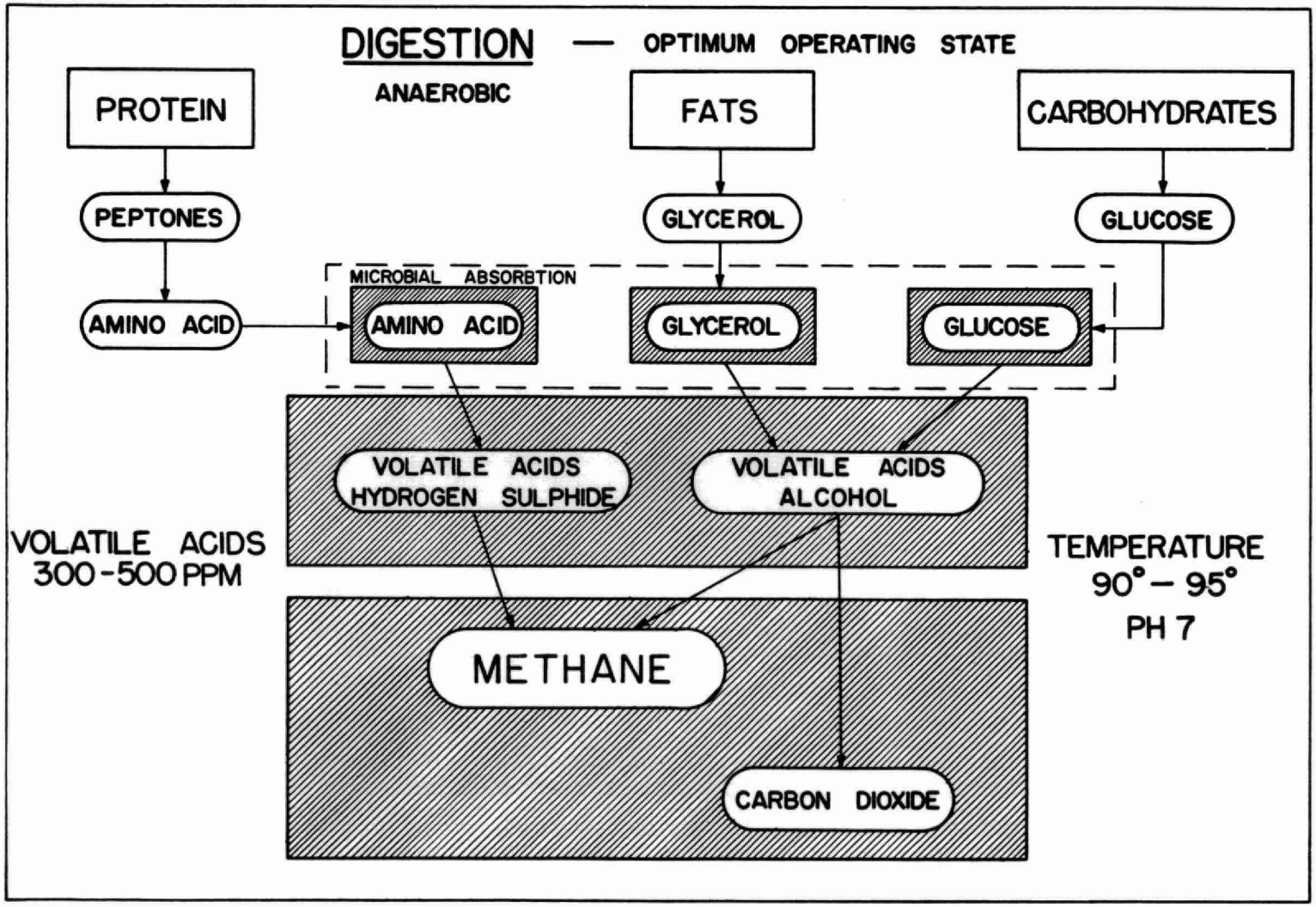
Where large volumes of sludge must be handled, vacuum filters are utilized to reduce the volume further by dewatering.

The filter consists of a porous drum around which is wrapped a cloth or steel-coil blanket. With the aid of chemical coagulants, the drum blanket picks up the sludge from a vat and, as the drum and blanket rotates, the sludge is dewatered by exerting a partial vacuum upon the blanket. A scraper edge removes the dewatered sludge cake and it drops onto a conveyor for delivery to a disposal area.

Sludge Drying Beds

In smaller installations sludge drying beds provide the means for dewatering.


BASIC ANAEROBIC ALKALINE DIGESTION PROCESS
RAW SLUDGE
ORGANIC MATTER HYDROLIZED BY ENZYMES
VOLATILE ACIDS CREATED BY BACTERIA CALLED ACID FORMERS
METHANE GAS CREATED BY BACTERIA CALLED METHANE FORMERS
METHANE GAS & WATER
CARBON DIOXIDE
TRACE GASES
RESIDUAL ORGANIC MATTER
INORGANIC MATTER


DIGESTION — OPTIMUM OPERATING STATE
ANAEROBIC
PROTEIN
FATS
CARBOHYDRATES
PEPTONES
GLYCEROL
GLUCOSE
MICROBIAL ABSORBTION
AMINO ACID
AMINO ACID
GLYCEROL
GLUCOSE
VOLATILE ACIDS
HYDROGEN SULPHIDE
VOLATILE ACIDS
ALCOHOL
VOLATILE ACIDS
300-500 PPM
TEMPERATURE
90° – 95°
PH 7
METHANE
CARBON DIOXIDE

WHY WATER PURIFICATION PLANTS?

Water-borne diseases, such as typhoid, are almost unknown in Ontario now, thanks to strict control of private and municipal water systems.

As may be expected, the quality of the source of supply has much to do with the degree and type of treatment necessary. All surface-water supplies contain bacteria, but as well they may be turbid, colored, or contain algae. Turbidity is the term applied to the finely-divided suspended and colloidal material which is too light to readily settle out of water. Color in water is caused by dissolved organic matter, which results from decaying bacteria and vegetation. Bacteria must be removed to protect the public health.

The object of treatment is to use the most effective processes and equipment to remove impurities found in each specific source. For this reason, the following methods and items all may be used in a plant, or only a few may be required, depending on the quality of the source of supply. Outlined are typical water treatment processes and equipment.

TYPICAL WATER TREATMENT PROCESSES AND EQUIPMENT

(SURFACE WATER SUPPLY)

Low Lift Station

A low lift station is a raw water receiving station and reservoir, which is equipped with pumps, motors, screens and other miscellaneous equipment. The intake pipe extends out from this station into the lake or river and the raw water enters the raw water reservoir by gravity flow.

Located in the building, at the terminal point of the intake, is a bar screen, which obstructs the passage of any large objects entering the intake. Following this is usually stationary or travelling fine screens, which remove as much of the screenable material as possible, before the water enters the raw water reservoir.

The low lift station, then, is a pumping station for the delivery of the raw water to the treatment plant, and houses the equipment which provides initial screening for the removal of the larger impurities.

Microstrainer — Algae Removal

A microstrainer is a rotary drum resting on a concrete frame and is covered with a cloth or steel-mesh blanket. The blanket openings are measured in microns, with the size selected being dependent on the type of algae encountered.

In operation the drum rotates and, as the water passes through, the algae contained in the water is enmeshed on the blanket. Most units are equipped with an ultra-violet light attachment, which acts as a germicidal agent on the water. Periodically the microstrainer is backwashed or flushed with water under pressure, to remove the accumulated algae and clean the blanket. The wash water is discharged to waste.

Flocculation — Color, Turbidity and Bacteria Removal

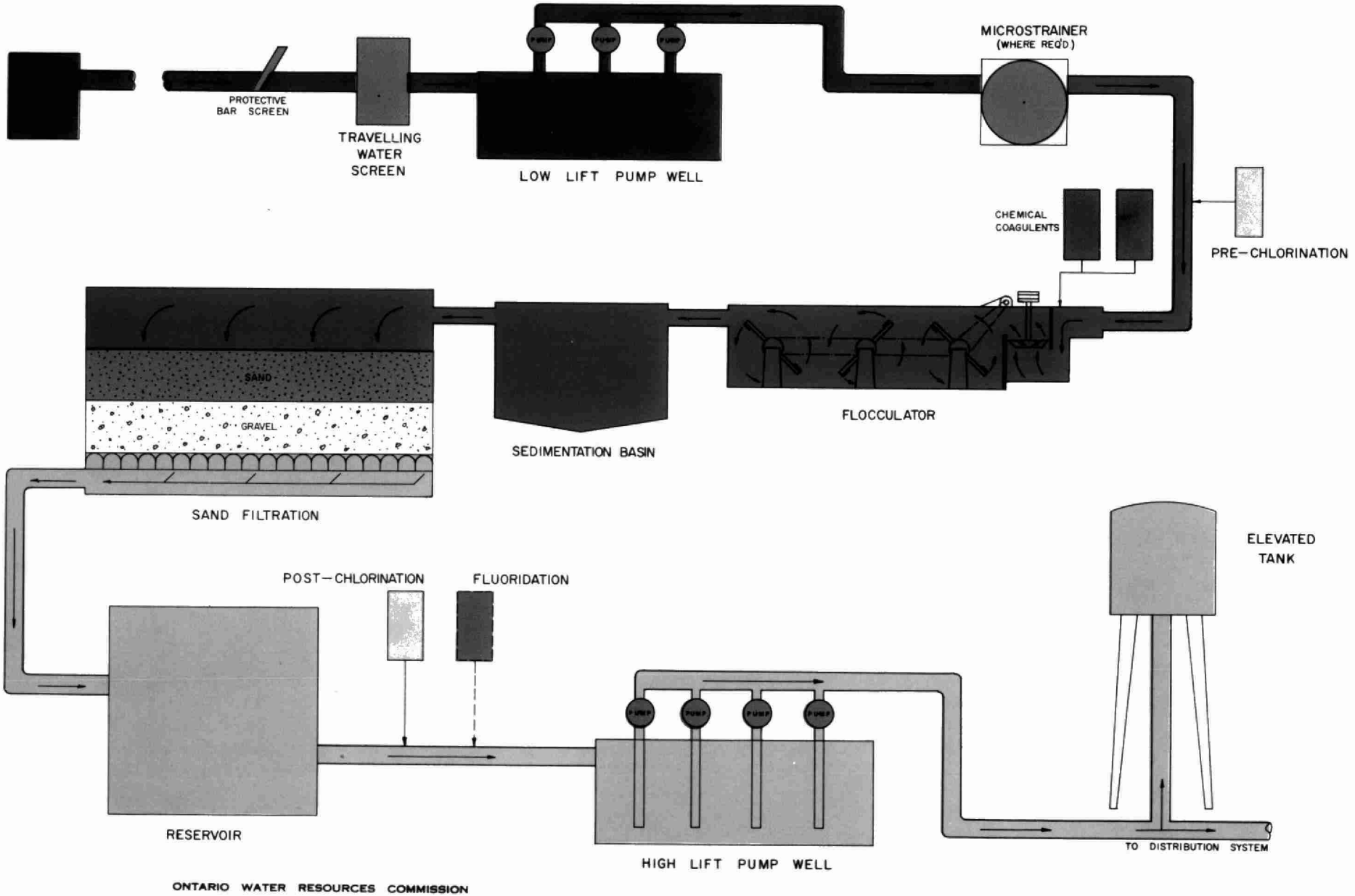
A flocculator is a concrete structure equipped with large paddle-wheels, which rotate to agitate and mix the water passing through. At the entrance end of the flocculator is a small mixing chamber equipped with a revolving blade mixer.

In operation, chemical coagulants such as alum, lime and ferric sulphate, are fed into the mixing chamber with the water. These coagulants form gelantinous, sticky precipitate, which absorbs color and entangles mud, bacteria and suspended matter. The flocculator's agitation allows this gelatinous mass to build up into clumps, or floc, which are readily removed by settling.

WATER TREATMENT

TYPICAL FILTRATION PLANT

SURFACE WATER SUPPLY



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A settling basin follows the flocculator where the treated water undergoes a detention period of sufficient time to allow for the settling of the floc. This basin may be equipped with sludge removal facilities for periodic removal of the floc.

Filtration — Turbidity and Bacteria Removal

There are two main types of conventional filters used to remove minute impurities from water, the gravity filter and the pressure filter.

The gravity filter is a concrete basin or tank equipped with a straining system (media) and underdrains for the passage of filtered water. The filter media may consist of graded sand and gravel, graded sand and gravel with a top dressing of anthrafilt, or anthrafilt alone. (Anthrafilt is a type of hard coal carefully crushed to a desired size). The filter also is equipped with back-washing facilities for the periodic cleaning of the media of accumulated impurities.

In operation, the raw or conditioned water flows by gravity through the filter and the impurities contained in the water are transferred to the media. The filtered water then passes through the underdrains into a clear water reservoir.

The pressure filter is a steel tank consisting of the same filter media materials as the gravity filter, except the water is forced through under pressure.

Chlorination — Destruction of Bacteria

The complete removal of pathogenic bacteria (disease organisms) is essential in all water supplies. Water which has been treated efficiently should be free of harmful bacteria. To ensure this, chlorine is applied as a germicidal agent before it is delivered to the consumer.

Chlorine is sometimes utilized in the early stages of treatment for bacterial reduction. When used for this purpose, it is referred to as pre-chlorination. Chlorination immediately before delivery to a reservoir or the consumer is referred to as post-chlorination.

Fluoridation

Where a local municipality or a local board owns or operates a water works system in Ontario, the council of the municipality may by by-law establish, maintain and operate a fluoridation system in connection with the water works system.

The council may, before passing such a by-law submit the question, whether or not to fluoridate the communal water supply, to the electors of the municipality.

IRON REMOVAL

Where the iron content of a municipal water source is objectionably high, a pressure filter equipped with an aerating device may be used to reduce the amount of iron. Since iron contained in water is dissolved, oxygen must be introduced to oxidize the iron. As it oxidizes, it becomes insoluble and can be removed by a filter. The oxygen required is supplied by an air compressor.

A gravity or pressure filter may be used to remove the insoluble iron. In smaller communities a pressure filter is more economical both to construct and to operate. Both types of filter media are comprised of the same material.

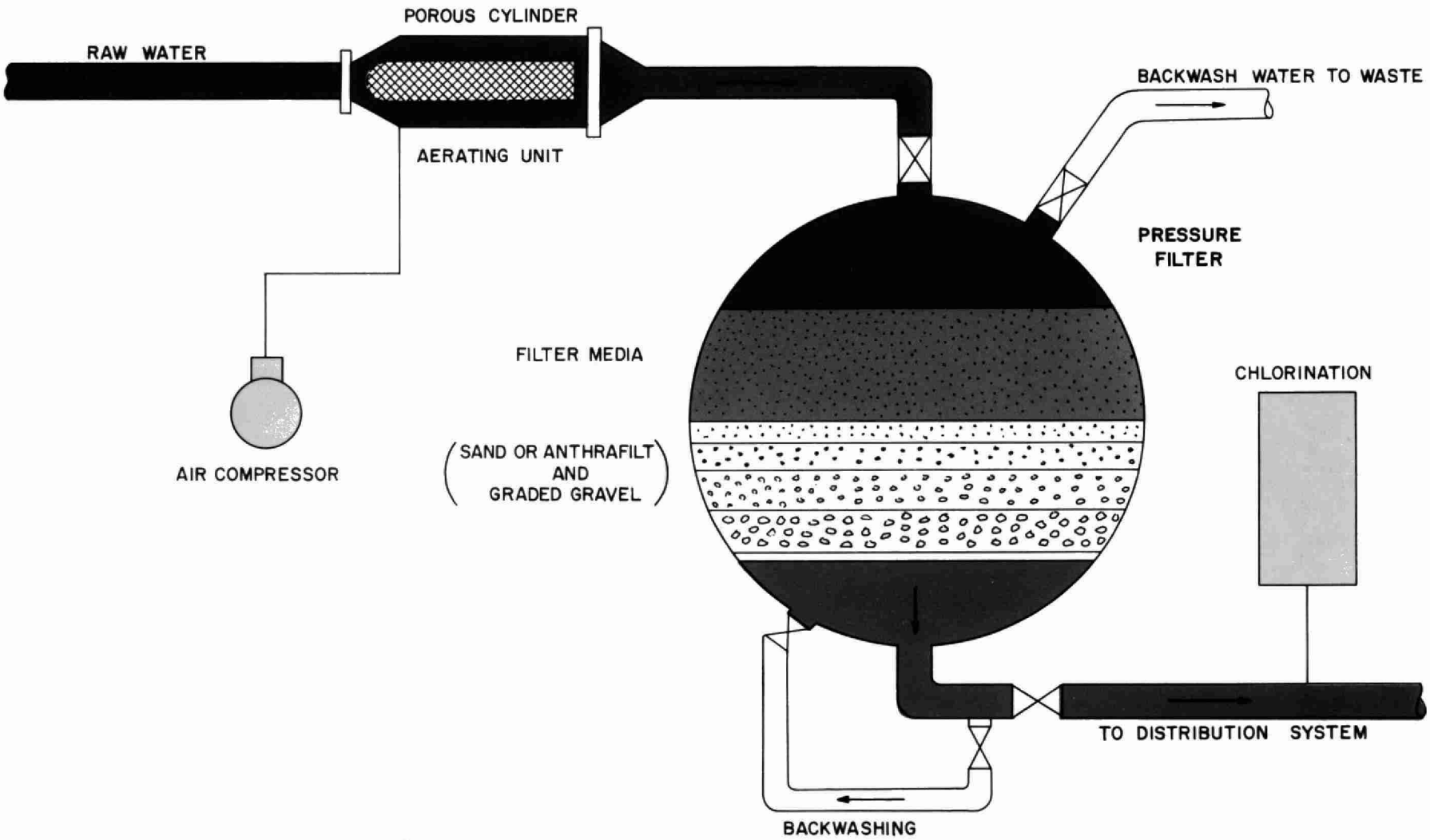
The pressure filter is a circular tank equipped with a straining system (media) and underdrain system for the passage of filtered water. The media may consist of graded sand or anthrafilt and gravel. (Anthrafilt is a type of hard coal carefully crushed to a desired size). The filter is also equipped with backwashing facilities to remove the accumulated iron deposits from the filter media.

In operation, the raw water passes a porous cylinder in the pipe which discharges oxygen in the form of fine bubbles. This oxidizes the iron and as the water flows down through the media, the iron is removed. The filtered water is then piped to a clear water reservoir.

The treated water is chlorinated to ensure the complete removal of pathogenic bacteria before discharge to the municipal system.

WATER TREATMENT

IRON REMOVAL



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